Project Planning Tool: Task-Level Information Template

Project Title: ***Protecting water while developing energy and mineral resources*** (SSWR 3.03)

Task Title: ***Evaluate cumulative impacts of fossil fuel and mineral extraction activities on aquatic life from changes in land use, water quantity and quality, and habitat availability***

Task Lead: Brent Johnson

Task Start Date: FY16
Task End Date: FY19

Task Description:
Energy and mineral extraction processes and their supporting infrastructure have potential to alter landscapes, fragment and degrade habitat, and impact both water quality and quantity. Water quality and habitat can be impacted by both release of wastewaters and excess sedimentation to streams. Mountaintop removal and valley fill (MTM/VF) coal mining is a widespread practice throughout the central Appalachians. By this method, coal seams are exposed by complete removal of overburden that is disposed of by placing it in adjacent valleys, creating valley fills (VF) that completely bury headwater streams. MTM/VF has altered landscapes on a regional scale and resulted in the burial of thousands of miles of headwater streams (USEPA 2003). Sediments ponds are constructed at the base of valley fills to facilitation deposition of suspended solids, however, total dissolved solids (TDS) are extremely elevated as a result of groundwater leaching freshly disturbed fill materials. Because there are no viable treatment options for TDS removal, dissolved ion concentrations, measured as stream conductivity, are often more than 100 times greater in MTM/VF streams than in unmined streams of the region (e.g. Bryant et al 2003, Fritz et al. 2010, Johnson et al. 2010). Further, stream conductivity can remain elevated for decades following fill construction (Merricks et al. 2007) and numerous studies have now demonstrated potential adverse impacts of elevated conductivity from MTM/VF activities on stream biota (e.g. Merricks et al. 2007, Pond et al. 2008, Pond 2010, Johnson et al. 2013).

The cumulative impacts of energy and mineral extraction activities, such as MTM/VF, may lead to ecological disturbance and impair watershed integrity on a regional scale. The Clean Water Act (§404[e][1]) requires consideration of cumulative impacts of permitted activities, yet measurement of cumulative impacts is difficult due to a lack of appropriate assessment methods, difficulties associated with the large temporal and spatial scales, and potential interactions of multiple stressors. As a result, the cumulative effects of multiple permitted activities (e.g., mines, wells, etc.) within watersheds remain poorly understood despite previous measurement efforts (e.g., Lidbergh et al. 2011, Johnson et al. 2010, USEPA 2003). Novel sampling approaches, experimental designs, and methods of statistical analysis, are therefore needed to better evaluate stressors across multiple spatial scales to ensure protection of downstream water quality and ecosystem integrity. Such knowledge will lead to more informed regulatory practices at both state and federal levels.

Furthermore, identification of existing tools and evaluation of the capability of these tools to provide, or be adapted to provide, decision makers with policy relevant information for influences of mineral/energy extraction technologies on water availability/use, quality, and associated public health risks is needed. A decision support tool(s) would allow decision makers to evaluate specific energy production/mineral extraction scenarios (i.e., combinations of technologies in a particular geographic context) in order to:

- Understand the implications of deploying different technologies relative to the short and long term availability of water;
- Evaluate different scenarios with respect to water re-use and water discharged post-use;
- Relate water use to water availability on a regional scale; and
- Compare the impacts of different development scenarios on water quantity within and across regions.

The overall goal of this task is to apply novel statistical and modeling approaches to spatially explicit field data to better understand and quantify cumulative effects of coal mining in the Appalachian region. Information gained and summarized from this research can be applied to mine permitting activities and lead to more informed decision-making by regulators in the Office of Water, EPA Regions, and states. Methods used in this task for evaluating cumulative effects of watershed disturbance may also be translated to other disturbance types beyond MTM/VF and in other regions of the United States. Field data collected for this task will also be associated with laboratory and mesocosm toxicological studies included in Task 3.03A, *Assessing and predicting the ecological effects of wastewaters associated with energy and mineral extraction activities*.

Research Approach:

EPA Region 4 (Water Protection Division, Atlanta) has collected extensive field data (water chemistry, habitat, fish, benthic macroinvertebrates) from a mined watershed in eastern Kentucky for the purpose of evaluating *Cumulative Impacts of Mining in Eastern Kentucky* (CIMEK) (Figure 1). On a quarterly basis in 2013, sixty site locations (Figure 2) were sampled within the Right Fork Beaver Creek watershed. Sites were scattered within the watershed to provide longitudinal spatial coverage, from headwaters to mainstem, with emphasis on tributary junctions. Sampling included surface water grab sampling (e.g., metals, nutrients, total suspended and dissolved solids, sulfate, chloride, alkalinity, hardness) measurement of in situ physicochemistry (e.g, temperature, dissolved oxygen, pH, specific conductivity, and turbidity), and flow (stream velocity) measurements. In addition, habitat quality, benthic macroinvertebrates and fish were collected once at each station within the appropriate biological index periods. Benthic macroinvertebrate community data were used to calculate the Kentucky Macroinvertebrate Bioassessment Index (MBI) score for each site. Similarly, the Kentucky Index of Biotic Integrity (KIBI) was used to score fish community assemblages at each site, and fish tissue was analyzed for metals concentration.

These data will be analyzed using a number of conventional statistical methods along with geospatial and modeling approaches. The research will span multiple spatial scales, from site-

specific information to watershed and regional modeling efforts for areas with intensive mining and drilling operations (e.g. central Appalachia). Conventional analytic approaches (e.g., correlation, regression, principal components analysis, nonmetric multidimensional scaling) will be used to assess impacts of mining on water quality and stream biota and findings will be compared to other Appalachian mining studies (e.g., Lindbergh et al. 2011, Pond 2010, Pond et al. 2008,). These analysis will specifically evaluate downstream mining disturbance, and any accumulating effects, by incorporating watershed area and/or river kilometer as measures of stream size and longitudinal position within the stream network.

Geospatial tools will be used to further quantify and assess the degree of correlation among sample sites based on downstream distance within the stream network (e.g., Bivand et al. 2008). By this approach, downstream extent of mining disturbances can be accurately quantified. Stream chemistry and biotic variables will also be geostatistically modeled so that spatial predictions can be made for unsampled locations (Ver Hoef et al. 2014). Furthermore, land use data will be incorporated and species composition (beta diversity) will be measured and modeled within the watershed, further allowing discrimination of mining impacts from natural spatial and temporal variation (e.g., Legendre 2014, Legendre and Gauthier 2014, Podani et al. 2013, Dray et al. 2012, Blanchet et al. 2008)

Findings will contribute to a state-of-the science synthesis of cumulative effects of these activities on water resources. The need for development of a decision support tool will be facilitated through participation in the multiagency collaboration on unconventional oil and gas research.

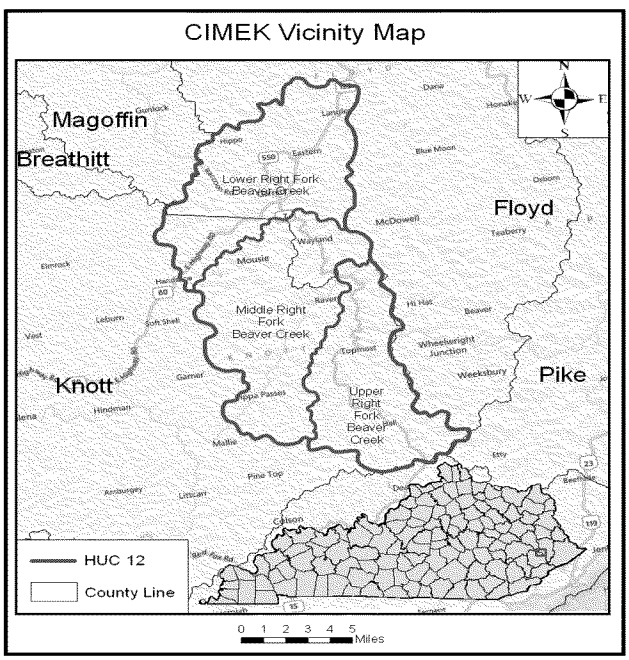

Figure 1. Case study watersheds for the Cumulative Impacts of Mining in Eastern Kentucky (CIMEK) project

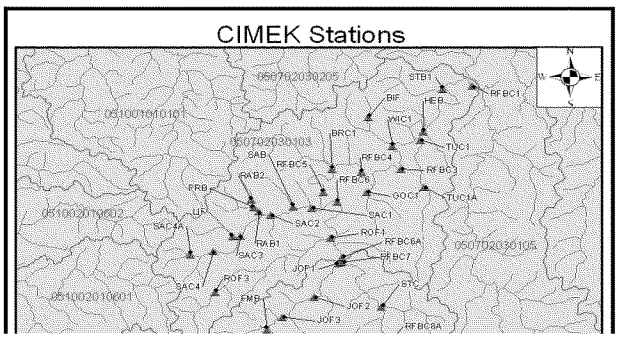

Figure 2. Map of study site locations for the Cumulative Impacts of Mining in Eastern Kentucky (CIMEK) case study.

Task Constraints:
Assumes available funding for GIS support of spatial analyses and modeling efforts.

Task Dependencies:
Nothing identified.

Task Quality Assurance and Data Management Needs:
QAPP Completed (NERL QA tracking #QA-EERD-66)

Task Products:
For each Product to be developed under this task provide the following:

Product 1:

- *Product Title*: Cumulative impacts of mountaintop mining on water chemistry and stream biota in an eastern Kentucky watershed
- *Product Contact (email):* johnson.brent@epa.gov
- *Product's Delivery Date*: FY17
- *Product Description*: Quantification of stream solutes by watershed area (or river mile) and correlation with mined watershed area. Correlation of water chemistry, habitat, fish and macroinvertebrate assemblages, and landuse using bivariate and multivariate statistical approaches. Evaluates loss of sensitive taxa associated with increasing levels of disturbance and identifies stressors most responsible for any observed species losses. Correlation of species extirpation constants (XC95's) with multivariate ordination axes of community data. Seeks development of predictive model for stream confluences to further evaluate potential downstream impacts.
- *Product's Contribution to Output*: Describes how stream solutes (ions) specific to mining impacts may accumulate in a downstream direction with increasing mining impacts. Provides a holistic, ecosystem level perspective of potential impacts and cumulative impacts of mountaintop removal mining on water quality and stream biota and identifies stressors of significance.
- *Product's Timeline (with milestones):*
    a. Data delivered from EPA Region 4, collated and QA'd: July 30, 2015

b. Correlation of water chemistry with watershed area/river mile and with mined watershed area upstream: Dec. 31, 2015
c. Milestone – Report on Downstream influence of mining on water chemistry presented to EPA Regions 3 and 4, April 1, 2016
d. Completion of multivariate statistical analysis of benthic macroinvertebrate data and correlation with abiotic data: Oct 1, 2016
e. Draft manuscript for peer reviewed publication presented to EPA Regions 3 and 4, March 1, 2017

- *Product's intended user/customer/audience*: EPA Regional Offices, EPA Office of Water, State regulatory agencies, Army Corps of Engineers, and other permitting agencies and professionals considering mining permit applications, aquatic life criteria for specific conductance or its correlates.
- *Is this a key product? No*
- *Does this Product contribute to a Product under another Task?* If so, identify other Task. Aspects of this product will contribute to 3.03 Task A, relating species sensitivity to stream specific conductance and solute (ion) concentrations. Results of this watershed study will be related to results of laboratory and mesocosm studies also included in Task A.

Product 2:

- *Product Title*: Spatial analysis and modeling approaches to assess cumulative impacts of mining
- *Product Contact (email)*: mcmanus.michael@epa.gov and martin.roy@epa.gov
- *Product's Delivery Date: FY18*
- *Product Description*: Use of an exploratory spatial data analysis (ESDA) method to create spatially lagged scatter plots whereby sites are binned into distance classes and correlations are compared among the distance classes. Moran scatter plots can also be used to check for spatial autocorrelation both in terms of distance between points, but also by proximity of which catchments are neighbors of other catchments. Use linked micromaps to summarize the catchment data on land cover and use, stream chemistry associated with the pour point of that catchment, and biotic response variable with that catchment. Build a stream network geodatabase in ArcGIS, and use that with the Spatial Stream Network (SSN) package in R to geostatistically model stream chemistry and biotic variables so that spatial predictions can be made. Measurement and modeling of beta diversity using multivariate analyses and spatial eigenvector mapping. This approach will allow partitioning of observed variation in species composition data spatially, temporally, and by environmental factors. The analyses will also identify factors responsible for observed diversity from site to site and what environmental factors may have greatest influence.
- *Product's Contribution to Output*: Evaluates potential mining impacts in a spatial context and helps to directly quantify cumulative effects with stream distance measures. Further provides a comprehensive view of potential cumulative impacts by incorporating spatial analyses to further explain observed differences in species

community composition, from individual sites to the watershed scale and relates to land use.

- *Product's Timeline (with milestones):*
  - *a.* Data delivered from EPA Region 4, collated and QA'd: Oct. 30, 2015
  - b. Data georeferenced for spatial analyses: March 1, 2016
  - c. Development of ESDA, linked micromapping, and creation of SSN for the study watershed: Sept 1, 2016
  - d. Completion of spatial analytical processes: Sept. 1, 2017
  - e. Two draft manuscripts, "Spatial contiguity to assess cumulative impacts of land use on stream chemistry and biota" and "Evaluation of novel modeling approaches for assessing the spatial and temporal interfaces between ecological diversity and environmental drivers across mined watersheds" submitted for peer reviewed publication and presented to EPA Regions 3 and 4, March 1, 2018
- *Product's intended user/customer/audience*: EPA Regional Offices, EPA Office of Water, State regulatory agencies, Army Corps of Engineers, and other permitting agencies and professionals considering mining permits, aquatic life criteria for specific conductance or its correlates.
- *Is this a key product?* No
- *Does this Product contribute to a Product under another Task?* If so, identify other Task.
- Aspects of this product will contribute to 3.03 Task A, relating species sensitivity to stream specific conductance and solute (ion) concentrations. Results of this watershed study will be related to results of laboratory and mesocosm studies also included in Task A.

Product 3:

- *Product Title*: State-of-the-science review of cumulative impacts of fossil fuel development on water quality and quantity
- *Product Contact (email):* johnson.brent@epa.gov
- *Product's Delivery Date*: *FY19*
- *Product Description:* A summary report of Task C findings in addition to a review of current scientific literature on cumulative effects of fossil fuel and mineral development on natural resources.
- *Product's Contribution to Output*: This product will summarize known and potential impacts of cumulative effects of water resources and will therefore better inform permitting agencies and those responsible for establishing aquatic life criteria.
- *Product's Timeline (with milestones):*
  - a. Completion of literature review relative to cumulative effects of fossil fuel and mineral extraction, Jan. 1, 2018
  - b. Receive preliminary results from Products 1 and 2 for inclusion, March 31, 2018
  - c. Draft EPA Report for external review Jan. 31, 2019 presented to EPA Regions and Office of Water
- *Product's intended user/customer/audience*: EPA Regional Offices, EPA Office of Water,

State regulatory agencies, Army Corps of Engineers, and other permitting agencies and professionals considering mining permits, aquatic life criteria for specific conductance or its correlates.

- *Is this a key product*? No
- *Does this Product contribute to a Product under another Task?* If so, identify other Task No

Task Resources:

Task Level Extramural Resources

Lab or Center receiving money: NERL and NCEA
Division: NERL/EERD and NCEA-Cincinnati
Contact name: Brent Johnson (NERL/EERD)

Extramural (NPD RAP) in $K

- FY16: $50K
- FY17: $50K
- FY18: $50K
- FY19: $25K

Description of Extramural needs for each FY:
What science efforts are the funds needed for? Is there specific timing (i.e., contracts)?

- FY16: $50K, GIS support for georeferencing data and mapping support
- FY17: $50K, GIS support for spatial data analyses and support for statistical consulting
- FY18: $50K, GIS support for mapping and support for technical writing and statistical consulting
- FY19: $25K GIS support for mapping and support for technical writing and statistical consulting

Description of impact on Product delivery (or contribution) if resources are not available in a timely manner?
Product 2 requires extensive GIS support for completion of proposed data analyses. Product 3 relies heavily on completion of Products 1 and 2.

Proposed method for Extramural Need:
GIS and statistical consulting contracts

Task Level Intramural Resources

Intramural (L/C Corporate) in $K

- FY16: $5K
- FY17: $5K

- FY18: $5K
- FY19: $5K

Description of Intramural Needs for each FY:

- FY16: $5K Travel to scientific meetings and software upgrades
- FY17: $5K Travel to scientific meetings and software upgrades
- FY18: $5K Travel to scientific meetings and software upgrades
- FY19: $5K Travel to scientific meetings and software upgrades

Special Task Level Resource Needs and Considerations

Special facilities or equipment needed:
None

Identify any of the following that apply:

- High performance computing/visualization: *GIS*
- *Task is in fulfillment of Technical Support Request to ORD from EPA Region 4 through OSP*

Task Staffing:

Staff Member	L/C	Division	Expertise	Contribution to Project or Task	FY16 % FTE	FY17 % FTE	FY18 % FTE
Brent Johnson	NERL	EERD	Ecology	Co-PI	0.50	0.50	0.50
Mike McManus	NCEA	NCEA-Cinci	Ecology and Spatial Statistics	Co-PI	0.35	0.35	0.35
Roy Martin	NERL	EERD	Ecology and Ecological Modeling	Co-PI	0.25	0.25	0.25
Michael Griffith	NCEA	NCEA-Cinci	Ecology	Co-PI	0.1	0.1	0.1
Sue Norton	NCEA	NCEA-D.C.	Ecology	Multiagency UOG collaborative	0.1	0.1	0.1

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